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DARK FILAMENTS OBSERVED AT 8.3mm AND 3.1mm WAVELENGTHS

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ABSTRACT

Mapping of the sun was made at 3.1mm (98 GHz) and 8.3mm (36 GHz) wavelengths with a 45m dish radio telescope at the Nobeyama Cosmic Radio Observatory. The depressions associated with large Hα filaments are derived to be -0.2 at 8.3mm and -0.05 at 3.1mm, which are darker than the values inferred by Raoult et al. (1979).

INTRODUCTION

The radio observations of the filaments are valuable for studying the physical conditions in and surrounding the prominences. The spatial resolutions of the radio observations, however, are worse than those in the optical ones, and the determinations of the size and the brightenss temperature of the filaments are more or less affected by the antenna beam-width.

Many dark filaments have been observed at millimetric and centimetric wavelengths as brightness depressions on the disk. These observations are summarized in Table 1. Raoult et al. (1979) made a synthesis of the millimetric and centimetric observations of the quiescent prominences on the disk by correcting the instrumental beam-width and derived a spectrum of the brightness temperature of the radio filaments between 3.5mm and 6cm wavelengths. Apushkinskii and Topchilo (1976 a) presented the brigtness temperatures of 70 filaments, selected from 300 radio filaments observed at the Lebedev Physics Institute and 70 at the Crimea Astrophysical Observatory, and derived the height dependence of the temperature in the prominences. The prominence-corona transition region was studied by Chiuderi-Drago et al. (1975), Lantos and Raoult (1980), and Schmahl (1979). The weakening in the brightness depression after disparition brusque was observed (Kundu and Lantos, 1977). A radio observation of a prominence at mm-wavelength during a solar eclipse was carried out in order to obtain the structure and physical parameters of the prominence (Simon and Wickström 1971, Apushkinskii et al. 1976). Radio flux enhancements associated with the filaments were observed at 169 MHz (Axis et al., 1971)

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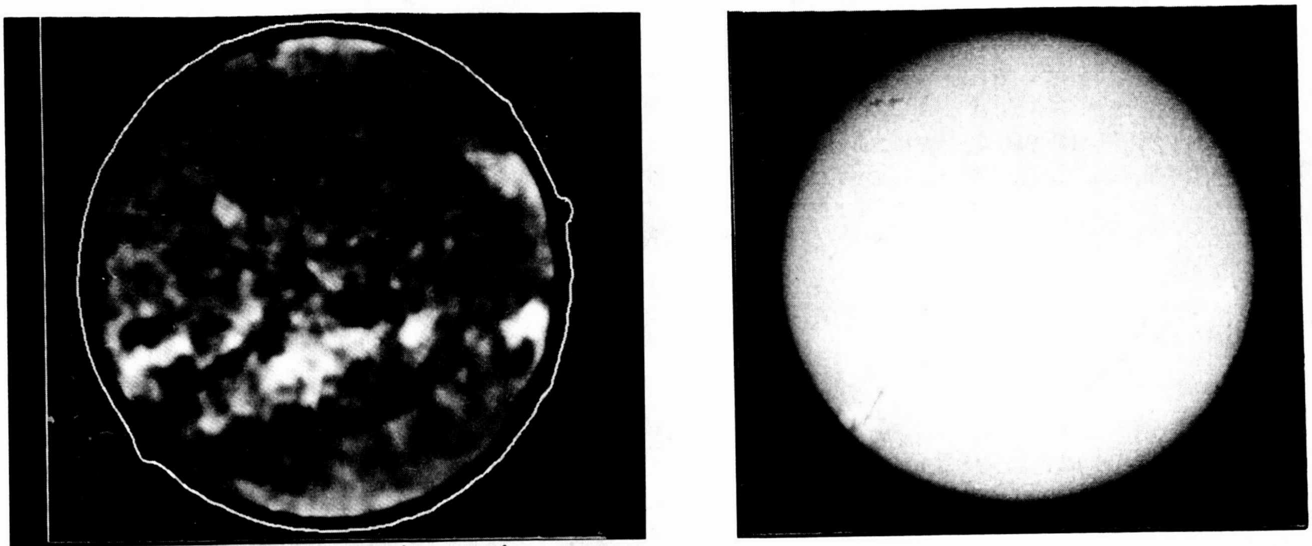
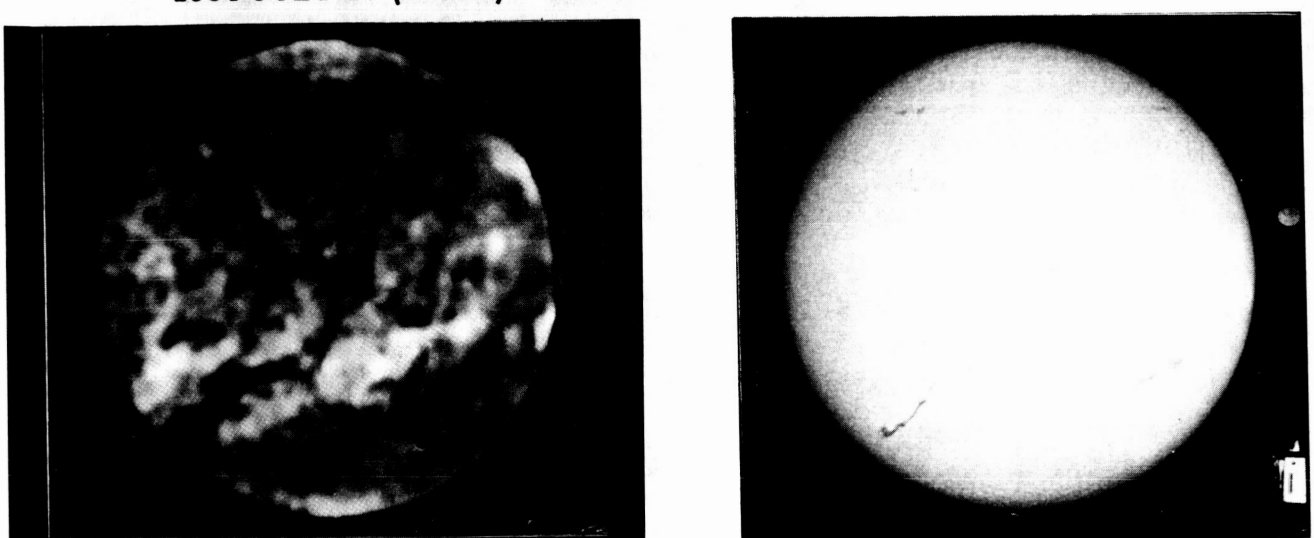
TABLE 1 OBSERVATION OF FILAMENTS

Wavelength	HPBW (arc min)	Telescope	Reference	
1.2 mm	1.2	36ft NRAO	Kundu	1970
2.0	1.2	22m Crimea	Efanov	1972
2.0		22m Lebedev	Apushkinskii et al.	1976a
2.25		22m Crimea	Efanov et al.	1969
3.1	0.28(17")	45m Nobeyama	Hiei et al.	1986
3.2	3.0	15ft Aerospace C.	Simon	1965
3.3	2.8	15ft Aerospace C.	Simon & Wickström	1971
3.5	1.2	36ft NRAO	Kundu	1970,1972b
			Kundu & Lantos	1977
3.5	1.2	36ft NRAO	Buhl & Tlamicha	1970
4.0	1.0	22m Crimea	Efanov	1972
4.0		22m Lebedev	Apushkinskii & Tsyganov	1973
4.0	1.2	13.7m Helsinki	Kundu et al.	1978
6.0		22m Crimea	Efanov et al.	1972
6.0		22m Lebedev	Apushkinskii et al.	1976a
7.0	0.9	120ft Haystack	Schmahl et al.	1971
8.0	1.7	22m Lebedev	Khangil'din	1964
8.0	1.6	22m Crimea	Efanov	1972
8.0		22m Lebedev	Apushkinskii	1976a,1976c
8.15		22m Crimea	Efanov et al.	1969
8.3	0.77(46")	45m Nobeyama	Hiei et al.	1986
8.5		22m Lebedev	Apushkinskii et al.	1976a
9.0	3.5	36ft NRAO	Kundu	1970
9.5	1.5	85ft NRL	Kundu & McCullough	1972a
1.2 cm	0.67	100m Effelsberg	Kundu et al.	1978
1.3	2.4	22m Crimea	Efanov	1972
1.35	1.5	120ft Haystack	Pramesh et al.	1977
1.36	1.4	120ft Haystack	Schmahl et al.	1971
1.6	3.0	22m Crimea	Efanov	1972
1.95	2.1	140ft NRAO	Chiuderi-Drago & Felli	1970
2.0	2.0	140ft NRAO	Tlamicha	1969
2.0	2.2	120ft Haystack	Schmahl et al.	1971
2.0	1.0	100m Effelsberg	Butz et al.	1975
2.0	2.2	120ft Haystack	Pramesh et al.	1977
2.8	1.25	100m Effelsberg	Fürst et al.	1973
2.8	1.25	100m Effelsberg	Kundu et al.	1978
3.8	4.4	120ft Haystack	Pramesh et al.	1977
3.8	4.1	120ft Haystack	Schmahl et al.	1981
3.8	4.4	120ft Haystack	Straka et al.	1975
6.0	2.6	100m Effelsberg	Chiuderi-Drago et al.	1975
6.0	2.5	100m Effelsberg	Kundu et al.	1978
6.0	0.25(15")	WSRT	Rao & Kundu	1980
6.0		VLA	Kundu	1985
11	5.0	100m Effelsberg	Kundu et al.	1978
20		VLA	Kundu	1985
1.78 m		Nanfay	Axisa et al.	1971
1.88		Culgoora	Dulk & Sheridan	1974
3.75		Culgoora	Dulk & Sheridan	1974



1984 JULY 17 (36GHz)



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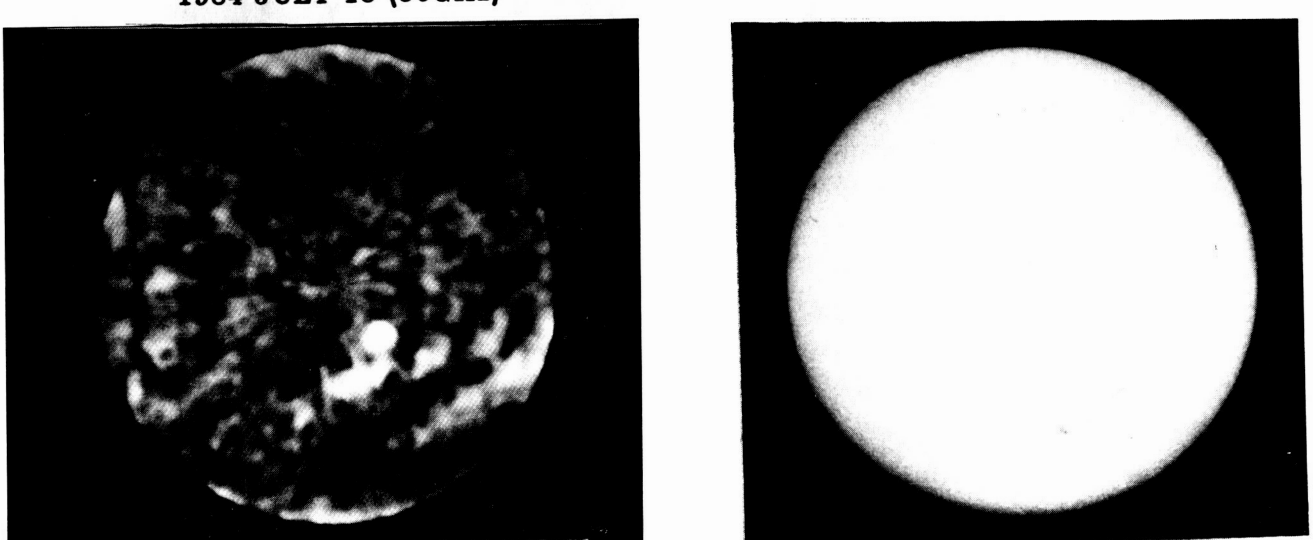

1984 JULY 22 (36GHz)

and at 80 and 160 MHz (Dulk and Sheridan, 1974). Recent understanding of the radio observations of the filaments are reported by Kundu (1979, 1985).

High quality maps at 36 GHz (8.3mm) and 98 GHz (3.1mm) were obtained with a 45-m radio telescope at the Nobeyama Cosmic Radio Observatory from 16 July to 22 July 1984. Their brightness temperature and its time change are discussed.

OBSERVATION AND ANALYSIS

The radio telescope and observation were described in detail by Kosugi et al. (1985) and only a short description is made here.

The angular resolutions of the 45-m dish telescope is of 46 arcsec (36 GHz) and 17 arcsec (98 GHz) at a half-power beam-width. The whole disk of the Sun were radially scanned in order to minimize the variation of the atmospheric attenuation due to the change of the weather condition during the observation. One scan length of 0.9° was made in 25 sec and the increment in the scan angle is 0.75° . Total 240 scans per 180° were carried out in 2 hours. In this radial-scan method the sudden change in the atmospheric attenuation within 25 sec is unavoidable, but the slow variation is corrected by using the brightness at the disc center.

The observations at 36 GHz were made at 5-7h UT on 16th, 0.5-2.5h UT on 17th, 0.5-2.5h UT on 18th, 1-3h UT on 19th, 23h on 21st - 1h UT on 22nd, 1-3h UT on 22nd, and 3-5h UT on 22nd July 1984, and the observations at 98 GHz at 6-8h UT on 17th, 1-3h UT on 19th, 23h on 21st - 1h UT on 22nd, 1-3h UT on 22nd, and 3-5h UT on 22nd July 1984. Simultaneous observations at 36 GHz and 98 GHz were made by using a beam splitter on 19th and 22nd July 1984.

Figures 1 show the radio maps and Hα filtergrams observed at Mitaka.

The comparison between the radio (36 GHz) and Hα features of the dark filaments shows the following results.

1) all Hα filaments correspond to the depressions on the disk, but not all depressions correspond to Hα filaments,
2) the positions of enhanced regions and the depressions move from east to west day by day. No systematic differnece in the positions between the radio maps and Hα filtergrams is found. Therefore the height of the depression is about the same as Hα filaments within the accuracy of the observation,
3) depression becomes deep when the size of Hα filament becomes large. This suggests that the instrumental dilution still affects the depression,
4) radio filaments, that can not be seen in Hα filtergrams, exist along the neutral line of the magnetic field,
5) there were three filaments, which could be seen at Hα filtergrams only in 1-2days. The depression seems to be appeared simultaneously with its corresponding Hα dark

filament, and the depression became weak but still seen after the disappearance of the Hα dark filament,

6) sometimes the depression appeared earlier than the Hα dark filament. On the depression in north-west disk on July 17, no Hα filament is seen, and on July 18, an Hα filament appeared there and the depression become darker than that on July 17. On July 19 the Hα filament was seen near the limb. Another example is seen at the depression near the disk center (south) on July 19. On July 18, the Hα filament is not seen, and the depression is also weaker than that on July 19,

7) a contour line on the radio map of July 17 (Figure 1) shows 1/8 level of the average brightness of the quiet Sun. The protuberances in east-south limb and in north-west limb are corresponding to the Hα prominences (McCabe 1986),

8) at 96 GHz (3.1mm), depression corresponding to an Hα filament is seen but weaker than that at 36GHz.

These observations may suggest that an Hα filament appear at a pre-existing depression channel. Therefore some depressions come from the prominences and the prominence-corona interface, and some appear before the appearance of an Hα filament and are seen after its disappearance. The other depressions, which are not corresponding to the dark filaments, is due to the different physical conditions of the chromosphere-corona transition region.

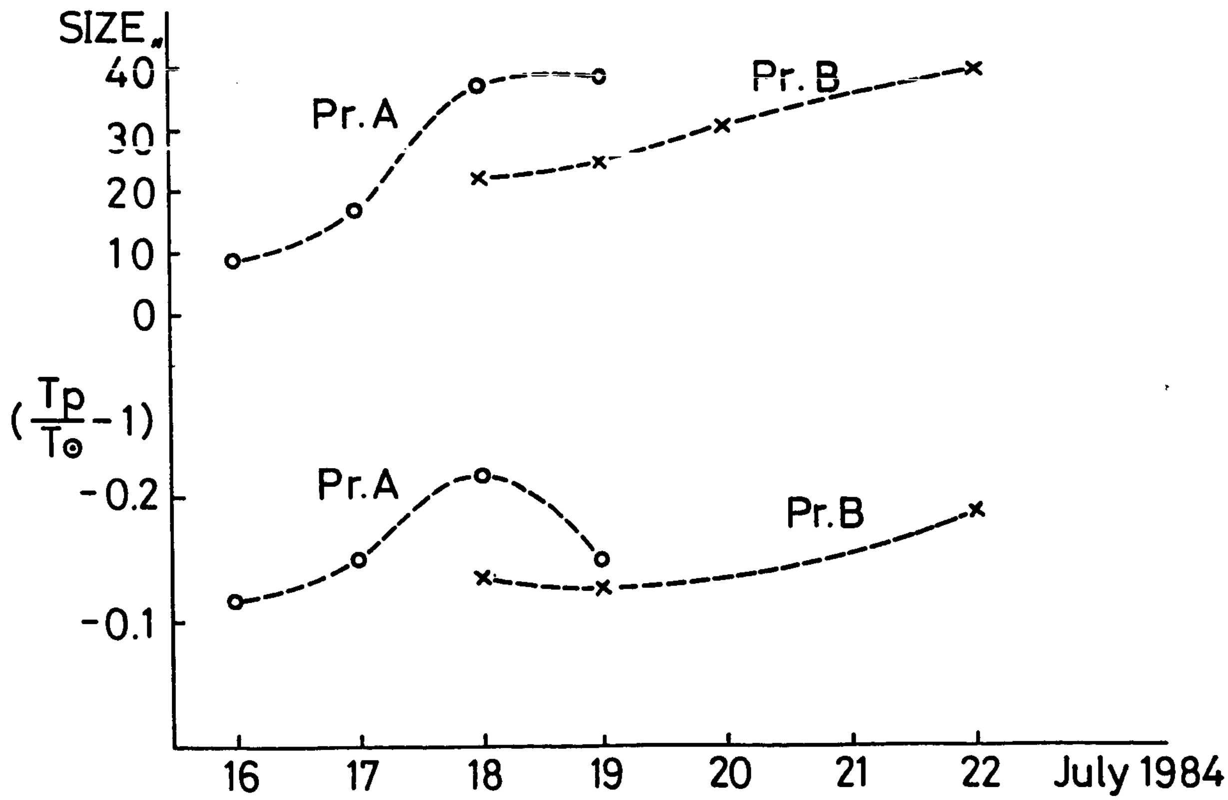

Figure 2

The diagram (Figure 2) shows the change of the value of depressions. The ordinate is (T_p/T -1), and the abscissa the day of July. The depression of prominence A (Pr. A) at 8.3mm becomes darker and darker, and again weaker. The depression of prominence B (Pr. B) becomes darker and darker. The above shows the width (size) of Pr. A and B. The size of Pr. A on 16 and 17 July is smaller than the antenna beam-width of 46 arcsec and the observed brightness is thought to be affected by the background quiet Sun. On 18 and 19 July, the size of Pr. A is about the same size as the beam-width, and the depression shows a value, not seriously affected by the quiet Sun. On July 19, the size of Pr. A is the same as that on July 18, but the depression becomes weak. Therefore, this depression is thought to be real. This will be due to the change of physical state in Pr. A, or to the change of the filling factor of the prominence.

The depression of -0.2 at 8.3mm for Pr. A and Pr. B is the lowest value at our observations.

The mean value of the depression at 8.3mm wavelength derived by Raoult et al. (1979) is about -0.1, which still seems to be affected by the background bright disk due to the lack of the spatial resolution.

If we take 8000° K as the brightness temperature of the quiet Sun at 8.3mm, and the depression is to be -0.2, then the temperature of the prominence is estimated to be $\sim$ 6600° K, which is consistent with the temperature derived from the spectroscopic study of the quiescent prominence. The temperature and electron number density, following Hirayama's review (1985) are Te$\sim$6500° K, and ne$\sim 10^{10.5}$. In this case the optical depth of the prominence at 8.3mm becomes 1 at only 40km depth, and therefore the optical depth at 8.3mm is quite large in quiescent prominences.

At 3.1mm, the depression is as small as -0.05. If we take 6500° K as the electron temperature of the prominence, the brightness temperature is estimated to be 6200° K.

The optical depth at 3.1mm becomes 1 at 280km depth. If the width of the filamentary structures of the prominence is about 300km, the each filament has $\tau=1$ at 3.1mm.

If the optical depth of the filament is large, then the residual brightness of the depression and the peak brightness above the limb should be the same. But if there exists some differnce between them, it means that filling factor must be taken into account in order to explain the difference.

CONCLUDING REMARKS

1) A group of the depressions on the radio map is larger than that of Hα filaments. The depressions are due to Hα filaments, or pre/aprés-filament state, or different physical state at the transition region between the

chromosphere and the corona.

2) T_p/T ratio is equal or smaller than 0.8 at 8.3mm and about 0.95 at 3.1mm.

3) If we adopt the prominence model of Te=6500K and ne=$10^{10.5}$, then τ=1 at 8.3mm corresponds to 40km length, and at 3.1mm to 280km length.

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